Effect of selected plant growth regulators on the performance of Damask rose (*Rosa damascena* Mill.)

Synopsis

Submitted in the partial fulfilment for the requirement of

Doctor of Philosophy

in

Botany

Submitted by

Krishan Kant

Under the supervision of

Dr. Akbar Ali

Department of Botany, Faculty of Science

Dayalbagh Educational Institute (Deemed to be University)

Dayalbagh, Agra 282005

2022

Introduction

Essential Oil (EO) is a mixture of heterogenous organic substances which are aromatic and volatile liquid obtained from plant material including bark, buds, flower, fruits, herbs, leaves, peel, rhizome, root, twig, seeds, wood, and whole plants. These are complex secondary metabolites, which are derivative of terpene, terpenoid, and phenyl propanoid (Brenes and Roura, 2010; Rios 2016) and EO secretory structures are oil cell, epidermal cell, gland, cavity, ducts, and trichomes (Lee and Ding, 2016). These are mostly used in the perfume industry (perfume, soap, shampoo, cosmetic, and cleaning gels), agrofood industry (Beverage and flavoring food), and pharmaceutical industry (Rios, 2016).

Damask rose (*Rosa damascena* Mill.) is the most important essential oil yielding industrial crop, belong the family *Rosaceae* and cultivated for its important application in aromatic, cosmetic, flavoring, perfumery, and pharmaceutical industries (Kumar *et al.*, 2013, Mahajan and Pal, 2020).

As the king of flowers, has long been associated with love, purity, inspiration, happiness, faith, and beauty (Mahboubi, 2016; Shabbir *et al.*, 2020; Mileva *et al.*, 2021), and in Persian and Iran, *R. damascena* Mill. is known as "Gol-E-Mohammadi" i.e., the flower of Prophet Mohammad (Moein *et al.*, 2010; Shabbir *et al.*, 2020). Its name "Damask Rose" is derived from the city of Damask in Iran. Which is known for fabrics (Damask), steel (Damask steel), and roses (Thallaj, 2020).

In Damask rose, the growth rate, flower and oil yield, and essential content and composition are largely affected by various factors, such as genetic factors, environmental factors (biotic and abiotic stress), species variety, climatic and cultivation conditions, pre-harvest factors such as soil fertility and nutrients, agronomic practices (mulching, time and level of pruning, date, time of flower harvesting, and storage time), the transportation and retention condition of flowers and methods of distillation technology (Kumar *et al.*, 2016; Pal and Mahajan, 2017).

Damask rose is the main species of Bulgaria, and Turkey, but is cultivated in many parts of the world for essential oil and medical aspects. Nowadays it is cultivated in different countries such as Afghanistan, Chile, China, Crimea, France, Egypt, Germany, India, Iran, Italy, Japan, Libya, Morocco, North America, North Korea, Pakistan, South France, South Russia, Syria, and Ukraine (Kumar *et al.*, 2013; Kumar *et al.*, 2016; Pal *et al.*, 2016; Mahajan and Pal, 2020; Mileva *et al.*, 2021). Damask rose

has been commercially cultivated in India since the time of the Mughals. Although, its cultivation has remained restricted to some area of Bihar, the Himalayan region (Kashmir and Himachal Pradesh), Haryana, Rajasthan, Punjab, and Uttar Pradesh (Aligarh, Ettawa, Gazipur, Hathras, Kannauj, and Lucknow) (Singh and Singh, 2001; Patra *et al.,* 2002; Kumar *et al.*, 2016), and occupying around 2500–3000 hectares of land and yielding about 200 kg of rose essential oil and rose attars, as well as a significant amount of rose water (Verma *et al.,* 2011).

The common products obtained from *R. damascena* are rose absolute, rose hips, dried rose, rose essential oil, rose concrete, rose tea, rose water and fresh petal are used in gulkand (jam of rose) (Mahboubi, 2016; Mahajan *et al.,* 2020). Bulgaria and Turkey are the main producer of rose oil which is 85% of the global essential oil market (Pal *et al.,* 2016). The annual global production of damask essential oil is ranged from15 to 20 Metric Tons (MT), but its demand is around 45 MT. The essential oil of the damask rose is the costliest of all aromatic crops in the global market with prices ranging from 10,000 to 12000 US dollars/Kg (In the Indian market price varies 7 to 10 lakh/Kg (Thakur *et al.,* 2019, Thakur and Kumar, 2020) and for a high price in the global market, it is called fluid Gold (Kumar *et al.,* 2016).

Foliar application of Plant Growth Regulator (PGR) is the most important practice for significantly increase the flower and essential oil yield, chemical composition and quality of Damask rose oil (Pal *et al.,* 2016; Pal and Mahajan, 2017; Mahajan and Pal, 2020; Thakur and Kumar, 2020). Foliar spray ensures fast translocation of nutrients and movement of minerals are usually faster through the stomata, but the total absorption may be higher through the epidermis, and it is an alternative approach to enhance the Nutrients Use Efficiency (NUF) in acidic soil (Pal *et al.,* 2016; Kumar *et al.,* 2016).

Why need to research on Damask rose?

- Its low production of flowers and oil content is major problem of farmers.
- Its rose essential oil and other products of rose demand is very high in global market (Kumar *et al.,* 2016).
- Damask rose have huge need in industries like as pharma sectors, perfumery, cosmetic and culinary (Mahboubi, 2016; Mahajan *et al.,* 2020).
- The price of essential oil is very high.

- There is no cultivation of Damask rose in this area.
- Now a days, it a serious challenge for researchers, farmers, and manufactures, because plants lose their ability to grow and develop with time, resulting in reduced flower yield and essential oil yield (Thakur and Kumar, 2020).

Triacontanol (TRIA)- TRIA is ($CH_3(CH_2)_{28}CH_2OH$) fatty alcohol plant growth regulators, which have plant growth regulator activity discovered by Ries *et al.,* (1977) in alfalfa and found in the form of epicuticular waxes (Naeem *et al.,*2011). It is dynamic growth regulator in stress condition (Karam and Keramat, 2017). TRIA has been shown to improve plant growth, yield, photosynthesis, enzyme activity, nitrogen fixation, free amino acids, reducing sugars, and soluble protein, according to several studies (Naeem *et al.,*2011).

Naphthalene Acetic Acid (NAA)- NAA ($C_{10}H_7CH_2CO_2H$) is synthetic plant growth regulators and in appropriate concentrations, improves the potential of plants and functions as a growth controller to boost crop productivity (Ullah *et al.,* 2021). NAA regulates phototropism, apical growth, respiration, and bud initiation (Horibe and Makita, 2021).

Salicylic Acid (SA)-Salicylic acid ($C_7H_6O_3$) is also known as ortho-hydroxybenzoic acid and 2-hydroxybenzoic acid, which is phenolic nature and endogenous plant growth regulator (Raskin, 1992; Babasheikhali *et al.,* 2020). SA helps in flowering induction (Raskin, 1992), minimal dilution of SA enhances the antioxidant activity of plants and activates the heat shock proteins (Sedaghat *et al.,* 2017). It controls photosynthesis, transpiration, stomata closure, ion uptake, ethylene biosynthesis inhibition and stress tolerance in plants (Babasheikhali *et al.,* 2020).

Review of Literature

Description of *Rosa damascena* Mill.

Classification of *Rosa damascena* Mill.	
Kingdom	Plantae
Subkingdom	Tracheobionta
Super division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Sub class	Rosidae
Order	Rosales
Family	Rosaceae
Genus	Rosa
Species	*R. damascena*

source: USDA Plants Database

Fig. 1 *Rosa damascena*

R. damascena Mill. is a perennial, hardy and deciduous shrub, which economic life about 20 to 30 years and bush height of about 2.5 meters (Fig.1). The stem possesses stiff glandular bristles and curved (falcate) spines, and having stipulate, pinnately compound leaves with 5 and rarely 7 leaflets. Colour of rose pink and light red, the flowers have 17-25 petals in bloom form. All flowers are actinomorphic, i.e., symmetrical. Accessory fruits (rose hip) with oblong-ovate shape, orange red to violet-red in colour. Most of the fruits fall off before ripening and the ones that remain produce 1–3 seeds. The tap root system consists of adventitious, highly developed ropelike skeletal branches formed by stem nodes and possesses a pronounced suction power (Shabbir *et al.,* 2020).

History of Origin

Many researchers believe that the *R. damascena* may have originated in the Middle East countries (Iran, Iran, Lebanon, and Syria) (Nayebi *et al.,* 2017; Shabbir *et al.,* 2020). The eastern Mediterranean region is also known as a center of production and called the center origin of *Rosa damascena*. It is assumed to have originated in South Anatolia during the Neolithic period as a hybrid of *R. gallica* and *R. phoenicea.* (Pal *et al.,* 2013).

Post-harvest technology of Damask rose-

The Damask rose is a once-a-year blooming plant that blooms for 35 to 45 days. The main flowering session in India is from March to April (in north Indian plains), and it is slightly late in hilly areas, during April and May (Pal *et al.,* 2016). Flowers are harvested by hand in early in the morning. After

harvesting, collected fresh rose flowers are delivered within 10 minutes to the distillatory unit (for extraction of oil), because after harvesting rose flowers are becoming fermented and lose aroma and essential oil yield. (Kumar *et al.,* 2013).

Varieties-

Out of 567 indigenous germplasm, the following varieties are cultivated in India 'Noorjhan' (developed by CIMAP, Lucknow from Aligarh region), 'Ranisahiba' (developed by CIMAP, Lucknow from Kannauj region) (Patra *et al.,* 2002), and 'Jwala', 'Super Jwala', 'Himroz' and 'Hot Himroz' are developed by IHBT, Palampur. 'Jwala' and 'Noorjhan' varieties are suitable for cultivation in subtropical northern regions, mid-hills, and mild temperate regions up to 1200 m altitude. While 'Himroz' is suitable for mild temperate to cold temperate regions 1200-2500 m altitude (Verma *et al.,* 2011; Kumar *et al.,* 2014).

Chemistry of rose oil and Active constituents

Damask rose essential oil is a mixture of volatile compounds such as monoterpenes, sesquiterpenes, aromatic alcohols, oxides, ethers, esters, and aldehydes. Acyclic monoterpene alcohols (citronellol, geraniol, and nerol), aromatic alcohol (phenylethyl alcohol), and long-chain hydrocarbons (nonadecane, nonadecene, eicosane, heneicosane, and tricosane) are all present in high concentrations in rose oil (Mahajan and Pal, 2020). Valuable products of Damask rose such as aroma and color are mainly synthesized from Shikimic acid and Methylerythritol 4-Phosphate (MEP) pathways (Rasouli *et al.,* 2018). Major compound of these variety of Damask rose oil are β-Citronellol (Fig. 2a) + nerol (16.3%-35.3%), Geraniol (15.8%-35.0%) (Fig. 2b), Nonadecane (11.3%-16.0%), Heneicosane (3.5%-13.8%), Heptadecane (1.3%-1.8%), cis-Rose oxide (0.9%-2.6%), β-Myrcene (0.5%-2.4%), α-Terpineol (2.9%-3.4%), Pinene (1.8%-2.8%), Linalool (0.7%-2.8%), Phenyl ethyl alcohol (0.1%-2.9%), Eugenol (0.3%-2.2%) and Germacrene D (1.1%-1.8%) (Patra *et al.,* 2002; Verma *et al.,* 2011; Kumar *et al.,* 2014; Nunes *et al.,* 2017).

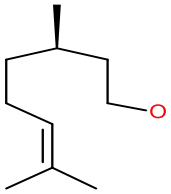
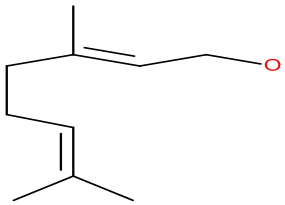
2a.  **2b.** 

Figure 2 Major chemical components of damask rose oil: (a) Citronellol and (b) Geraniol

Industrial uses- Rose essential oil one of the most important source raw material in the perfume industry and also used in a different product like cosmetics, beverages, alcoholic liquors, cold drinks, soft drinks, foodstuffs, tobacco flavoring, fruit flavors, rose tea, gulkand, dried rose powder, rose shop and medicines (Mahboubi, 2016; Mahajan *et al.,* 2020).

Pharmacological properties- Damask rose such as anticancer effect, antimicrobial activity, anti-inflammatory activity, anti-diabetic activity, cardiovascular effect, respiratory effect, antioxidant activity, neuroprotection effect and memory enhancement, effect against dementia, analgesic effect, anti-HIV effect, anti-stress activity, anti-ulcer, anti-lipase, hypnotic effect, an anticonvulsant effect, soothing effect, gastrointestinal effect, culinary effect, and cosmetic properties (Nayebi *et al.,* 2017; Shabbir *et al.*, 2020).

Naphthalene Acetic Acid (NAA)

Tonder *et al.,* (2003) studied that the PGRs effect on tomatoes (*Lycopersicum esculentum*) in greenhouse. They reported that 1ml/L of NAA was enhanced the fruit mass and tomatoes yield.

Son (2004) studied that spray effect of the NAA on fruit size and quality in 'Beliana' apricot (*Prunus armeniaca*) and he reported that maximum fruit size (52.76g) and the soluble solid (13.53%) in fruit was observed at 20 ppm NAA.

Kirmani *et al.,* (2013) studied that the effect of NAA, $CaCl_2$ and GA_3 on *Prunus salicina* and they reported that the preharvest treatment of 60 ppm NAA resulted in the greatest increase in fruit size and weight at harvest.

Ullah *et al.,* (2013) studied that the effect NAA and IBA on *Tagetes ercta* L. (Mari gold) and they reported that maximum branches/plant were observed with at 400 ppm NAA (5.0) and at 400 ppm IBA

(10.7), maximum plant height was observed with at 100 and 200 ppm NAA (7.80 cm) and at 100 ppm IBA (9.40 cm), maximum leaf/plant observed with at 100 ppm IBA (44.0) and maximum root/plant observed with at 400 ppm NAA (123.2).

Ibrahim (2018) studied that the foliar effect of Benzyl adenine (BA) and Naphthalene acetic acid (NAA) on Rosa hybrid at concentration at 200 mg/L increased flower yield and plant growth.

Nartvaranant (2018) studied that the foliar spray effect of NAA and 2,4-D on fruit fall in Pummelo (*Citrus maxima*) and all treatments were treated twice to chosen pummelo branches, first when they were in full bloom and again two months following fruit set. He reported that fruit fall was decreased, and the proportion of fruit retained in pummelo when 20 mg L^{-1} of NAA was sprayed two times at full bloom and two months after fruit set.

Horibe and Makita (2021) studied that the effect of NAA on three rose species (Princess Meg, Red Star, and Madrid) and reported that at 1000 µM concentration of NAA increased flower opening, flower weight and diameter.

Ullah *et al.*, (2021) studied that that foliar spray of NAA on maize (*Zea Mays* L.) in drought stress tolerance and reported that foliar spray of NAA in drought stress condition enhanced seed vigor index, germination rate index, carotenoid content, total biomass, soluble protein content, superoxide dismutase and peroxidase activity, root–shoot ratio, leaf area ratio, chlorophyll a and b content under high drought stress (15 day).

Triacontanol (TRIA)

Naeem *et al.*, (2009) reported that at concentration 10^{-6} M of TRIA is significant for crop productivity, enzyme activity and photosynthesis in Hyacinth bean (*Lablab purpureus* L.) and **Naeem *at al.*, (2011)** reported that foliar application at concentration 10^{-6}M of TRIA is significant in growth regulation in *Mentha arvensis* L.

Singh *et al.*, (2012) studied that the foliar effect of TRIA on ginger (*Zingiber officinale* Rosc.) and they reported that foliar treatments 10^{-6} M at 25-day intervals enhanced the shoot and rhizome weight, shoot height, chlorophyll content, NPK content in leaf, carbohydrate and protein content in rhizome, oil

content and production of ginger and concentration at 5×10^{-5} of TRIA inhibits the yield and all physiological and biochemical activities.

Khan *et al.*, (2014) studied that the effect of TRIA alone and combination with gibberellic acid (GA_3) on physiological and biochemical activity, photosynthetic activity, and growth and essential oil content of fennel (*Foeniculum vulgare* Mill.) and reported that foliar treatment of TRIA (10^{-6}) + GA_3 (10^{-6}) enhanced the biochemical activity, essential oil content, growth and productivity of fennel.

Karam and Keramat (2017) studied that the effect of TRIA on *Coriandrum sativum* L. in adverse condition and reported that foliar treatments of 100 μM TRIA was more effective in salt stress and increased antioxidant enzyme.

Naeem *et al.*, (2017) studied that the individual and combined effect of PGRs [gamma irradiated carrageenan (IC), TRIA and 28-homobrasinolide (HBR)] on growth, yield, and quality of *Mentha arvensis* L. (Corn mint) and the individual concentration of foliar spray was at 80ppm (IC), 10^{-6}M (TRIA) and 10^{-7}M (HBR). They reported that in individual foliar spray of TRIA at dose of 10^{-6}M enhanced essential oil content (85.59%) and the combination of three PGRs (80 ppm IC + 10^{-6} M TRIA + 10^{-7} M HBR) found to be the best for majority of the growth, physiological, biochemical, and agronomic parameters investigated when compared to other applied treatments and the control.

Nabi *et al.*, (2020) studied that the effect of TRIA and Nickel (Ni) on photosynthetic efficiency and antioxidant machinery in *Mentha arvensis* L. and they applied foliar spray concentration at 10^{-6} M (TRIA), 60mg/kg, 80mg/kg doses of Ni. They reported that at 80mg/kg of Ni dose inhibited the growth parameters and TRIA dose at 10^{-6} M was enhanced photosynthetic efficiency and yield.

Ali and Perveen (2020) studied that the effect of TRIA(1μM) on photosynthetic activity, growth and yield in wheat (*Triticum aestivum* L.) and they reported that they foliar spray at 1μM of TIRA was significant yield (100 grain weight) and enhanced flavonoids, anthocyanin contents, photosynthesis rate (A), transpiration rate (E), stomatal conductance (gs), internal CO_2 concentration (Ci), and water use efficiency (A/E).

Salicylic Acid (SA)

Fariduddin *et al.*, (2003) the effect that of SA on net photosynthetic rate, nitrate reductase activity (NRA) and seed yield in *Brassica juncea* and they reported that spray at 10^{-5}M was best for photosynthetic rate, and seed yield.

Ghazijahani *et al.*, (2014) studied that the foliar spray effect of SA on Sweet basil (*Ocimum basilicum* L.) and they applied foliar spray at the two doses of SA (control and 1mM) with two level of solution strength (full and half). They reported that full length (1mM) of SA solution enhances biomass production, thicker stem and greater value of Fv/Fm.

Khanam and Mohammad (2017) studied that the foliar spray effect of different PGRs at dose 5×10^{-6} M[TRIA, NAA, SA, 6-Benzylaminopurine (BAP), Chloromequat (CCC), Gibberellic Acid (GA_3), and Indole-3- Butyric Acid (IBA), Kinetin (Kn), and Methyl Jasmonate (MJ)] on *Mentha piperita* (peppermint) and they reported that In *Mentha piperita*, SA demonstrated to be the most effective in increasing oil content, oil yield, menthol concentration, and menthol yield

Babasheikhali *et al.*, (2020) studied the that foliar spraying effect of SA on *Rosa hybrid* "Beverly Watson" in alkaline soil condition and they were reported that SA treatments were found to be successful in reducing the negative impacts of alkalinity in roses, as well as having good and beneficial impacts on the plant's growth and development. SA is sprayed on the leaves, increased leaf and stem fresh and dry weight at a dose of 0.5 mM.

Estaji and Niknam (2020) studied that the foliar treatments effect of SA on *Silybum marianum* L. in drought stress and they reported that foliar spray of SA at dose of 1mM was enhanced seed oil content and seed yield and significant effect in proline content, sucrose, total phenolic compounds, and total soluble carbohydrates in Silybum *marianum* L.

Mirkohi *et al.*, (2021) studied that the effect of SA on Statice (*Limonium sinuatum* (L.) Mill.) "Cut flower" and they applied at four dose foliar spray of SA solution (control, 1, 2 and 3 mM) every two weeks until the flowering stage was started. They reported that under a 1 mM SA treatment, the quantity of cut flowers produced per pot and growth features were dramatically boosted.

Ali *et al.*, (2021) studied that the foliar spray effect of SA on peach 'Flordaking' (*Prunus persica*) in during low temperature and they sprayed the plants with a foliar spray dosage of SA (control, 1, 2, and 3 mM) at three phases of fruit development, namely cell division, cell expansion, and pit hardening. They reported that SA at a concentration of 3 mM was shown to be the most efficient in preserving quality during low-temperature storage for a longer period of time.

Keeping this in mind, it is decided to study the effect of selected plant growth regulators on the performance of Damask rose. To achieve the goal, four experiments will be conducted on Damask rose at experimental farm of Botany Department, DEI, Agra, Uttar Pradesh, India.

The aim of the four experiments are as follows-

Objectives

1. To study the effect of the most suitable concentration of foliar spray of Triacontanol (TRIA) on the basis of growth characteristics, physiological, biochemical parameters and essential oil production of *Rosa damascena* Mill.
2. To work out the effect of optimum concentration of leaf-applied Naphthalene acetic acid (NAA) on the basis of growth characteristics, physiological, biochemical parameters and essential oil production of *Rosa damascena* Mill.
3. To investigate whether optimum concentration Salicylic Acid (SA) could enhance the growth characteristics, physiological and biochemical parameters and essential oil production of *Rosa damascena* Mill.
4. To study the best concentrations of combined application of TRIA, NAA and SA on growth characteristics, physiological, biochemical parameters and essential oil production of *Rosa damascena* Mill.

Work plan and Methodology

Experimental location

A field trial will be conducted to study the effect of foliar application of selective plant growth regulators on growth, yield and essential oil quality of *R. damascena*. The experimental farm is situated at

experimental farm (i.e., Botanical Garden/ Herbal Garden/ Rose Garden) of Dayalbagh Educational Institute, Dayalbagh, Agra, Uttar Pradesh, India.

Agroclimatic condition and soil analysis

Suitable agroclimatic condition as weather, temperature, rain, and humidity will be identified to cultivate *R. damascena* in Agra region and soil analysis will be analyze of an experimental farm.

Growth observations after treatments

i. Growth parameters-

a. Shoot length per plant

b. Root length per plant

c. Fresh weight of shoot per plant

d. Dry weight of shoot per plant

e. Fresh weight of root per plant

f. Dry weight of root per plant

g. Leaf area index

h. No. of branches per plant

i. No. of flowers per plant

j. No. of flower per branch

k. Flower length

l. Flower diameter

ii. Physiological and biochemical Parameter: -

a. Total chlorophyll content [Mackinney (1941) and Maclachlan and Zalik (1963)].

b. Total carotenoids content [Mackinney (1941) and Maclachlan and Zalik (1963)].

c. Leaf-nitrogen content (Lindner, 1944)

d. Leaf-phosphorus content (Fiske and Subba Row, 1925)

e. Leaf-potassium content (Hald, 1947)

f. Photosynthetic rate by Infrared Gas Analyzer

g. Nitrate reductase activity (Jaworski, 1971)

h. Carbonic anhydrase activity (Dwivedi and Randhwa,1974)

iii. Yield parameter: - Total flower and Oil yield and its active constituents will be recorded. The essential oil will be extracted by the hydro distillation using Clevenger's apparatus and then quantified gravimetrically according to Guenther (1972).

a. Flower yield per plant

b. Essential oil content per plant

$$\text{Oil (\% v/w)} = \frac{\text{Observed volume of oil (ml)}}{\text{Weight of sample (g)}} \times 100$$

- Oil content will be estimated by following formula-

c. Essential oil yield per plant

d. Citronellol content

e. Citronellol yield per plant

f. Geraniol content

g. Geraniol yield per plant

Chemical constituents will be analyzed by GC-MS (Reverchon and Senatore, 1994).

iv. Statistical analysis: - Statistical analysis will be done by SPSS statistical software.

References

1. Ali, H. M. M., & Perveen, S. (2020). Effect of foliar applied triacontanol on wheat (*Triticum aestivum* L.) under arsenic stress: a study of changes in growth, yield and photosynthetic characteristics. *Physiology and Molecular Biology of Plants*, *26*, 1215-1224.
2. Ali, I., Wang, X., Tareen, M. J., Wattoo, F. M., Qayyum, A., Hassan, M. U. & Ahmed, W. (2021). Foliar Application of Salicylic Acid at Different Phenological Stages of Peach Fruit CV. 'Flordaking' Improves Harvest Quality and Reduces Chilling Injury during Low Temperature Storage. *Plants*, *10*(10), 1981.
3. Brenes, A., & Roura, E. (2010). Essential oils in poultry nutrition: Main effects and modes of action. *Animal feed science and technology*, *158*(1-2), 1-14.

4. Dwivedi, R. S., & Randhawa, N. S. (1974). Evaluation of a rapid test for the hidden hunger of zinc in plants. *Plant and Soil*, *40*(2), 445-451.
5. Estaji, A., & Niknam, F. (2020). Foliar salicylic acid spraying effect on growth, seed oil content, and physiology of drought stressed *Silybum marianum* L. plant. *Agricultural Water Management*, *234*, 106116.
6. Fariduddin, Q., Hayat, S., & Ahmad, A. (2003). Salicylic acid influences net photosynthetic rate, carboxylation efficiency, nitrate reductase activity, and seed yield in *Brassica juncea*. *Photosynthetica*, *41*(2), 281-284.
7. Fiske, C. H., & Subbarow, Y. (1925). The colorimetric determination of phosphorus. *J. biol. Chem*, *66*(2), 375-400.
8. Ghazijahani, N., Hadavi, E., & Jeong, B. R. (2014). Foliar sprays of citric acid and salicylic acid alter the pattern of root acquisition of some minerals in sweet basil (*Ocimum basilicum* L.). *Frontiers in plant science*, *5*, 573.
9. Guenther E (1972) The essential oils: history-origin in plants production-analysis, (vol. 1), Robert E. Krieger publishing company, Huntington, New York
10. Hald, P. M. (1947). The flame photometer for the measurement of sodium and potassium in biological materials. *Journal of Biological Chemistry*, *167*(2), 499-510.
11. Horibe, T., & Makita, M. (2021). Promotion of flower opening in cut rose cultivars by 1-naphthaleneacetic acid treatment. *Ornamental Horticulture*.
12. Ibrahim, M. (2018). *Physiological and metabolic responses of two rose varieties to plant growth regulators* (Doctoral dissertation, Murdoch University).
13. Jaworski, E. G. (1971). Nitrate reductase assay in intact plant tissues. *Biochemical and biophysical research communications*, *43*(6), 1274-1279.
14. Karam, E. A., & Keramat, B. (2017). Foliar spray of triacontanol improves growth by alleviating oxidative damage in coriander under salinity. *Indian Journal of Plant Physiology*, *22*(1), 120-124.
15. Khan, M. M. A., Hashmi, N., Moinuddin, & Dar, T. A. (2014). Changes in growth, yield, photosynthetic characteristics, enzyme activities and essential oil production of fennel (*Foeniculum*

vulgare Mill.) under growth regulator treatments. *Journal of Essential Oil Research*, *26*(2), 105-113.

16. Khanam, D., & Mohammad, F. (2017). Effect of structurally different plant growth regulators (PGRs) on the concentration, yield, and constituents of peppermint essential oil. *Journal of Herbs, Spices & Medicinal Plants*, *23*(1), 26-35.
17. Khandan-Mirkohi, A., Pirgazi, R., Taheri, M. R., Ajdanian, L., Babaei, M., Jozay, M., & Hesari, M. (2021). Effects of salicylic acid and humic material preharvest treatments on postharvest physiological properties of statice cut flowers. *Scientia Horticulturae*, *283*, 110009.
18. Kirmani, S. N., Wani, G. M., Wani, M. S., Ghani, M. Y., Abid, M., Muzamil, S., & Malik, A. R. (2013). Effect of preharvest application of calcium chloride ($CaCl_2$), Gibberlic acid (GA_3) and Naphthenic acetic acid (NAA) on storage of Plum (*Prunus salicina* L.) cv. Santa Rosa under ambient storage conditions. *African Journal of Agricultural Research*, *8*(9), 812-818.
19. Kumar, R., Sharma, S., Kaundal, M., Sharma, S., & Thakur, M. (2016). Response of damask rose (*Rosa damascena* Mill.) to foliar application of magnesium (Mg), copper (Cu) and zinc (Zn) sulphate under western Himalayas. *Industrial Crops and Products*, *83*, 596-602.
20. Kumar, R., Sharma, S., Sood, S., & Agnihotri, V. K. (2013). Agronomic interventions for the improvement of essential oil content and composition of damask rose (*Rosa damascena* Mill.) under western Himalayas. *Industrial Crops and Products*, *48*, 171-177.
21. Kumar, R., Sharma, S., Sood, S., Agnihotri, V. K., Singh, V., & Singh, B. (2014). Evaluation of several *Rosa damascena* varieties and *Rosa bourboniana* accession for essential oil content and composition in western Himalayas. *Journal of Essential Oil Research*, *26*(3), 147-152.
22. Lee, Y. L., & Ding, P. (2016). Production of essential oil in plants: ontogeny, secretory structures and seasonal variations. *Pertanika Journal of Scholarly Research Reviews*, *2*(1).
23. Lindner, R. C. (1944). Rapid analytical methods for some of the more common inorganic constituents of plant tissues. *Plant physiology*, *19*(1), 76.
24. Mackinney, G. (1941). Absorption of light by chlorophyll solutions. *Journal of biological chemistry*, *140*(2), 315-322.

25. Maclachlan, S., & Zalik, S. (1963). Plastid structure, chlorophyll concentration, and free amino acid composition of a chlorophyll mutant of barley. *Canadian Journal of Botany*, *41*(7), 1053-1062.
26. Mahajan, M., & Pal, P. K. (2020). Flower yield and chemical composition of essential oil from *Rosa damascena* under foliar application of Ca $(NO_3)_2$ and seasonal variation. *Acta Physiologiae Plantarum*, *42*(2), 1-13.
27. Mahboubi, M. (2016). Rosa damascena as holy ancient herb with novel applications. *Journal of traditional and complementary medicine*, *6*(1), 10-16.
28. Mileva, M., Ilieva, Y., Jovtchev, G., Gateva, S., Zaharieva, M. M., Georgieva, A., & Najdenski, H. (2021). Rose flowers—A Delicate Perfume or a Natural Healer *Biomolecules*, *11*(1), 127.
29. Moazam Babasheikhali, M., Jabbarzadeh, Z., Amiri, J., & Barin, M. (2020). Impact of salicylic acid and nitric oxide on improving growth and nutrients uptake of rose in alkaline soil conditions. *Journal of Plant Nutrition*, *43*(5), 667-681.
30. Nabi, A., Parwez, R., Aftab, T., Khan, M. M. A., & Naeem, M. (2020). Triacontanol protects Mentha arvensis L. from nickel-instigated repercussions by escalating antioxidant machinery, photosynthetic efficiency and maintaining leaf ultrastructure and root morphology. *Journal of Plant Growth Regulation*, 1-19.
31. Naeem, M. M. M. A., Khan, M. M. A., Idrees, M., & Aftab, T. (2011). Triacontanol-mediated regulation of growth and other physiological attributes active constituents and yield of *Mentha arvensis* L. *Plant Growth Regulation*, *65*(1), 195-206.
32. Naeem, M., Aftab, T., Idrees, M., Singh, M., Ali, A., Khan, M. M. A., & Varshney, L. (2017). Modulation of physiological activities, active constituents and essential oil production of *Mentha arvensis* L. by concomitant application of depolymerized carrageenan, triacontanol and 28-homobrassinolide. *Journal of Essential oil rEsEarch*, *29*(2), 179-188.
33. Naeem, M., Khan, M. M. A., & Siddiqui, M. H. (2009). Triacontanol stimulates nitrogen-fixation, enzyme activities, photosynthesis, crop productivity and quality of hyacinth bean (*Lablab purpureus* L.). *Scientia horticulture*, *121*(4), 389-396.

34. Nartvaranant, P. (2018). The influence of exogenously applied 2, 4-D and NAA on fruit drop reduction in pummelo cv. Thong Dee. *International Journal of Fruit Science*, *18*(2), 215-225.
35. Nayebi, N., Khalili, N., Kamalinejad, M., &Emtiazy, M. (2017). A systematic review of the efficacy and safety of Ro*sa damascena* Mill. with an overview on its phytopharmacological properties. *Complementary therapies in medicine*, *34*, 129-140.
36. Nunes, H., & Miguel, M. G. (2017). *Rosa damascena* essential oils: a brief review about chemical composition and biological properties. *Trends in Phytochemical Research*, *1*(3), 111-128.
37. Pal, P. K., Mahajan, M., & Agnihotri, V. K. (2016). Foliar application of plant nutrients and kinetin modifies growth and essential oil profile in *Rosa damascena* under acidic conditions. *Acta Physiologiae Plantarum*, *38*(7), 1-14.
38. Patra, N. K., Kumar, S., Khanuja, S. P. S., Shasney, A. K., Kalra, A., Singh, H. B., & Sharma, S. R. (2002). *U.S. Patent Application No. 09/537,188*.
39. Raskin, I. (1992). Salicylate, a new plant hormone. *Plant physiology*, *99*(3), 799.
40. Rasouli, O., Ahmadi, N., Monfared, S. R., & Sefidkon, F. (2018). Physiological, phytochemicals and molecular analysis of color and scent of different landraces of *Rosa damascena* during flower development stages. *Scientia Horticulturae*, *231*, 144-150.
41. Reverchon, E., &Senatore, F. (1994). Supercritical carbon dioxide extraction of chamomile essential oil and its analysis by gas chromatography-mass spectrometry. *Journal of Agricultural and Food Chemistry*, *42*(1), 154-158.
42. Rios, J. L. (2016). Essential oils: What they are and how the terms are used and defined. In *Essential oils in food preservation, flavor and Safety* (pp. 3-10). Academic Press.
43. Sedaghat, M., Tahmasebi-Sarvestani, Z., Emam, Y., & Mokhtassi-Bidgoli, A. (2017). Physiological and antioxidant responses of winter wheat cultivars to strigolactone and salicylic acid in drought. *Plant Physiology and Biochemistry*, *119*, 59-69.
44. Shabbir, F., Hanif, M. A., Ayub, M. A., Jilani, M. I., & Rahman, S. (2020). Damask Rose. In *Medicinal Plants of South Asia* (pp. 217-230).

45. Singh, K., & Singh, V. (2001). Economics of cultivation and distillation of damask rose: A case study in Palampur (Himachal Pradesh). *Indian Journal of Agricultural Economics*, *56*(4), 696-707.
46. Singh, M., Khan, M. M. A., Moinuddin, & Naeem, M. (2012). Augmentation of nutraceuticals, productivity and quality of ginger (*Zingiber officinale*) through triacontanol application. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*, *146*(1), 106-113.
47. Son, L. (2004). Effects of hand and chemical thinning on fruit size and quality of 'Priana'and 'Beliana'apricot (*Prunus armeniaca*) cultivars.
48. Thakur, M., Bhatt, V., & Kumar, R. (2019). Effect of shade level and mulch type on growth, yield and essential oil composition of damask rose under mid hill conditions of Western Himalayas. *Plos one*, *14*(4).
49. Thallaj, N. (2020). Evaluation of Antimicrobial Activities and Bioactive Compounds of Different Extracts Related to Syrian Traditional Products of Damask rose. *Open Access Library Journal*, *7*(05), 1.
50. Ullah, S., Afzal, I., Shumaila, S., & Shah, W. (2021). Effect of naphthyl acetic acid foliar spray on the physiological mechanism of drought stress tolerance in maize. *Plant Stress*, *2*, 100035.
51. Ullah, Z., Abbas, S. J., Naeem, N., Lutfullah, G., Malik, T., Khan, M. A. U., & Khan, I. (2013). Effect of indolebutyric acid (IBA) and naphthalene acetic acid (NAA) plant growth regulaters on Mari gold (*Tagetes erecta* L.). *African Journal of Agricultural Research*, *8*(29), 4015-4019.
52. USDA Plants Database
53. van Tonder, CSM & Combrink, N. J. J. (2003). The effect of plant-growth regulators on the production of out-of-season greenhouse tomatoes (*Lycopersicum esculentum*). *South African Journal of Plant and Soil*, *20*(4), 165-168.
54. Verma, R. S., Padalia, R. C., Chauhan, A., Singh, A., & Yadav, A. K. (2011). Volatile constituents of essential oil and rose water of damask rose (*Rosa damascena* Mill.) cultivars from North Indian hills. *Natural product research*, *25*(17), 1577-1584